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YIELD ESCALATION EVALUATION

PROJECT RULISON

CER GEONUCLEAR CORPORATION

Las Vegas, Nevada

June 15, 1972

Contract No. AT(26-1)-429 between the U.S. Atomic Energy Commission, the U.S. Department of the Interior, Austral Oil Company, Incorporated, and CER Geonuclear Corporation.

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ILLUSTRATIONS

I. INTRODUCTION

Project Rulison is a joint experiment sponsored by Austral Oil Company, Inc., Houston, Texas, the U.S. Atomic Energy Commission, and the Department of the Interior, with Program Management provided by CER Geonuclear Corporation of Las Vegas, Nevada, under contract to Austral. Its purpose is to study the economic and technical feasibility of using underground nuclear explosions to stimulate production of natural gas from the low productivity, gas-bearing Mesaverde Formation in the Rulison field.

The nuclear explosive for Project Rulison was detonated sucessfully at 3:00 p.m. plus 0.1 seconds Mountain Daylight Time, September 10, 1969, at a depth of 8431 feet below ground level and was completely contained. Preliminary results indicate that the Rulison device behaved about as expected; i.e., with a yield of 40 $\pm\,^{20}_{4}$ KT. The wellhead of the emplacement well, Hayward 25-95A, is at an elevation of 8,154 feet above mean sea level (MSL) and is located 1,976.31 feet east of west line and 1,813.19 feet north of south line of Section 25, Township 7 South, Range 95 West of 6th p.m., Garfield County, Colorado, which corresponds to geodetic coordinates of longitude 107°, 56', 53" west and latitude 39°, 24', 21" north.

2. PURPOSE OF EVALUATION

This report provides the equations necessary to formulate [illegible] safety programs for future nuclear detonations in the [illegible] Rulison area. Using these equations, it is possible to apply predictive techniques to estimate the damage to be expected from such explosions. The formulae derived and the conclusions reached in this report are those of CER and no concurrence by the AEC is meant or implied.

The safety criteria presented are those that were used by the Atomic Energy Commission on the Rulison event. Their presentation does not imply CER's concurrence. The observed effects from the first Rulison detonation seem to indicate that the criteria are overly restrictive and that some relaxation could be made without increasing the safety hazard.

3. REGRESSION EQUATION DERIVATIONS

The equations shown in Appendix A are based on an analysis of the data (Appendix B) recorded during the Rulison explosion.[1,2] Only data from "hard-rock" stations were used in the analysis, no data from "alluvium" stations were used. The data have been edited as follows to eliminate doubtful and inconsistent data:

1. Independent calculations of the recorded velocities were made by the U.S. Coast and Geodetic Survey and the Environmental Research Corporation. When the computed results differed by more than 10 percent, the data were considered doubtful and eliminated from the analysis.

2. All stations with less than three components available for analysis were excluded.

3. Station R-08 was inside the Mobil mine, a situation which gives data that are subject to topographic effects; hence, these data were eliminated.

4. Stations R26 and R27 were located less than 1,000 feet apart in the town of Rifle; however, there were significant variations in the data. Station R26 was selected as being the most representative of a hard-rock station and data from Station R27 were eliminated.

5. The same situation existed with Stations R12 and R13 in the town of De Beque. Station R12 was selected as being the most representative of a hard-rock station situation and the data from Station R13 were eliminated. Subsequent microtremor surveys have confirmed the alluvium nature of Stations R27 and R13 justifying the elimination of their data from the analysis.

The equations resulting from this analysis of the Rulison data will be valid for point source or single device events. Whether or not these equations will hold for multi-device simultaneous detonations is open to question.

The analysis consisted of a linear "least square" fitting of the data by a single line in the logarithmic domain. The results are given in equation form in Appendix A and shown graphically in Appendix C. In the course of the analysis, the data seemed to split into two consistent sets with the split being at approximately 22 km. If the regression equations are derived on the basis of all the data from 0 to 296 km, the distant data (where no damage is expected) have too much influence on the regression analysis when compared with the influence of the close-in points where damage is expected. The use of the equations based on all the data (A_1, A_4, V_1, V_4, D_1, and D_4) will give pessimistic predictions from 0 to approximately 10 km, optimistic predictions from approximately 10 km to approximately 80 km, and pessimistic predictions beyond this distance. Therefore, it is recommended that Equations A_2, A_5, V_2, V_5, D_2, and D_5 be used for distances of less than 22 km and that Equations A_3, A_6, V_3, V_6, D_3, and D_6 be used for distances greater than 22 km.

4. [illegible]

Once the decision [illegible] een ma[illegible] [illegible] location, depth of burial, yield, and [illegible] of device, a seismic program can be formulated.

The type of device will determine the design yield and the maximum credible yield. Some types of devices have undergone more testing hence the uncertainty in yield is smaller. In the case of the Rulison device the design yield was 40 kt and the maximum credible yield was 60 kt. Other types of devices could decrease the difference between the design yield and maximum credible yield. Throughout the formulation of the seismic program the safety criteria should be based on the peak horizontal component of the acceleration predicted from the maximum credible yield.

By using the scaling formulae S_4, S_6, and S_8, the new prediction equations can be derived from the Rulison regression equations. In these equations the subscript 1 refers to the parameters of the proposed detonation and the subscript 2 refers to the Rulison parameters. The equations needed are for both the peak vector quantities and the peak horizontal components for the maximum credible yield.

The seismic effects program customarily used by the AEC involves dividing the area into several zones based on criteria which are values of the peak horizontal component of acceleration.

Zone 1

The first zone extends from the Emplacement Well (EW) out to a radial distance where the peak horizontal component of acceleration has attenuated to 0.3 g. Within this first zone a safety plan appropriate to this degree of acceleration should be prepared, approved, and executed. In the case of the Rulison event the plan for this zone called for evacuation of all non-detonation connected people from the area. In a few cases where families remained in the zone, each was monitored by a Public Health Service representative. In comparison with Rulison effects, this criterion appears to be excessively restrictive and John A. Blume & Associates has recommended that the AEC consider relaxing the criterion. The Rulison effects seem to indicate that a value of 0.5 g to 0.7 g would be realistic.

Zone 2

The second zone extends from Zone 1 out to a radial distance where the peak horizontal component of acceleration has attenuated to 0.1 g. Within this zone a safety plan appropriate to this degree of acceleration should be prepared, approved, and executed. For the Rulison event the plan for this zone called for all people to be outside any structures at a distance no less than twice the structure height. In cases where this was impractical special care was taken that people were at safe locations within the structure.

Zone 3

The third zone includes Zones 1 and 2 and extends from the EW out to a radial distance where the peak horizontal component of acceleration has attenuated to 0.03 g. Within this zone it is reasonable to expect some damage to structures, whereas outside this zone the probability of damage to structures, while not zero, is extremely small. Within this zone a careful structural inventory should be prepared. This inventory documents the location, condition, ownership, and value of structures in the zone and is useful in: 1) identifying seismically sensitive structures which require unusual precautions, and 2) cataloging postdetonation damage claims. This inventory also forms a fundamental part of any damage prediction technique. Where seismically sensitive structures or situations exist, precautions should be taken to avoid hazard to people or damage to structures; i.e., evacuation of the structures and/or bracing and predetonation repair. In areas which are prone to rock-, land-, and snowslides, special precautions (such as roadblocks) should be taken. Workmen in high places (linemen, steel workers, etc.) should be warned and, where possible, should avoid working in these places during the interval from detonation to ground motion passage. In cases where the motion might cause a psychological problem, special precautions should be taken; e.g., evacuation of schools.

Zone 4

The fourth zone extends from the outer limit of Zone 3 out to a radial distance where the peak horizontal acceleration has attenuated to 0.001 g. Outside this zone it is doubtful that the motion from the detonation can be perceived by humans. While no damage is expected outside of Zone 3, any structures in Zone 4 which are seismically sensitive should be identified and analyzed and, if necessary, precautions should be taken to avoid hazard to people or damage to structures; i.e., evacuation of the structures and/or bracing and predetonation repair. In areas which are prone to rock-, land-, and snowslides, special precautions (such as roadblocks) should be taken. Workmen in high places (linemen, steel workers, etc.) should be warned and, where possible, should avoid working in these places during the interval from detonation to ground motion passage. In cases where the motion might cause a psychological problem, special precautions should be taken; e.g., evacuation of schools.

5. FREQUENCY PREDICTION

In the past, predictions have been made of the frequency content of the ground motion by means of the pseudorelative velocity spectrum (PSRV) with 5 percent damping. This empirical technique is based on assumptions which may or may not hold. These predictions have been used mainly by the structural response contractor in estimating the risk to large or seismic sensitive structures in the area. Due to the uncertainties in the relationship of motion to damage and the limited uses of this type of prediction in the Rulison area, a simplified prediction technique appears justified.

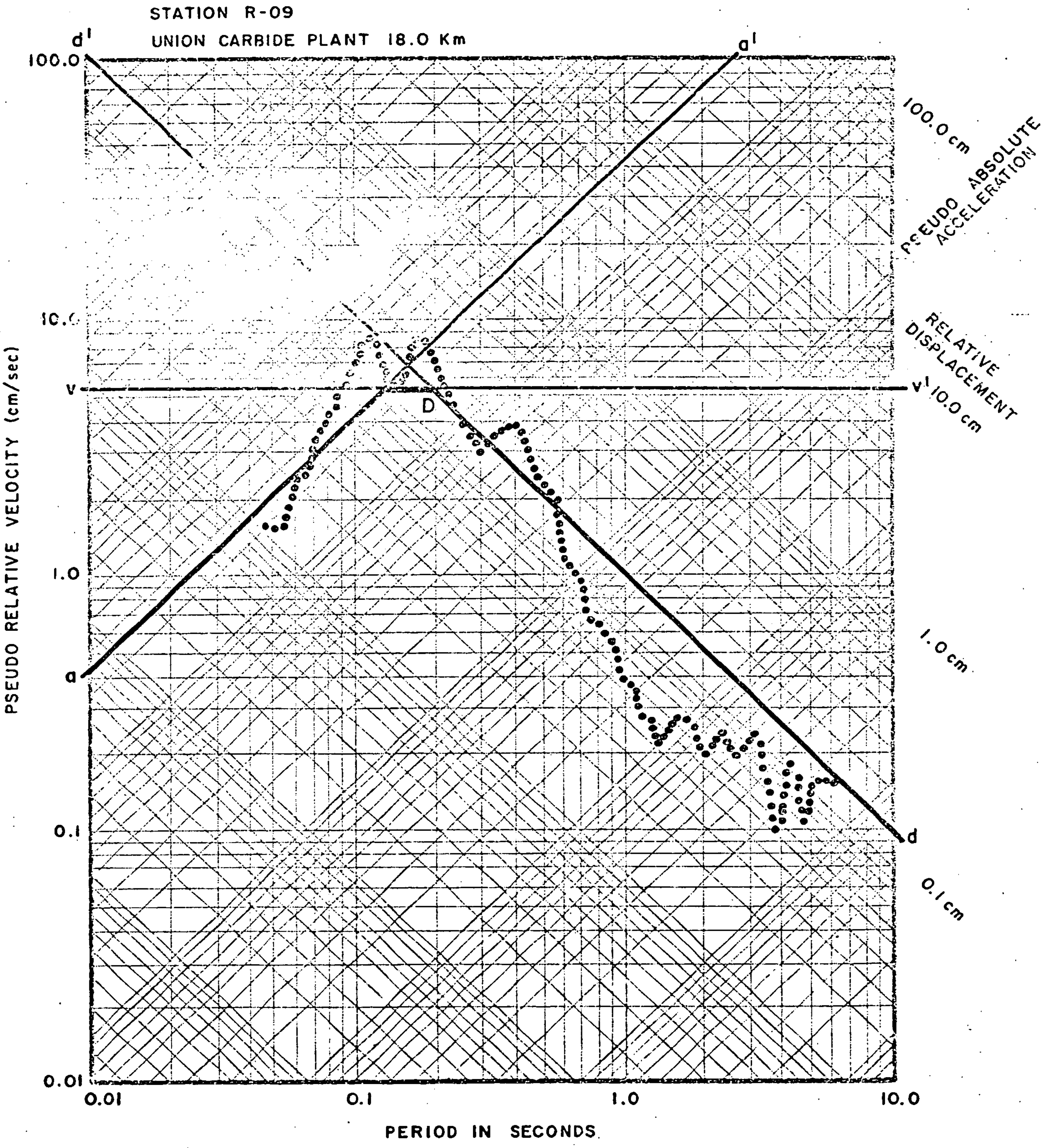
The following simple and inexpensive method is proposed for the empirical prediction of frequency content.

Equation S_4 is used to scale Equation A_7 to the given yield and depth of burial. This scaled equation then can be used to calculate the average pseudoabsolute acceleration (PSAA) at the desired location. This value of the average PSAA determines line aa' on Figure 1.

Equation S_6 is then used to scale Equation V_7 to the given yield and depth of burial. Using this scaled equation the value of the PSRV is calculated. This value determines line vv' on Figure 1.

A distance is now measured along vv' starting at the intersection of aa' and vv' in the direction of increasing period and equal to the distance between 0.2 and 0.3 seconds measured on the period scale. This establishes point D which in turn establishes the line dd' on the average relative displacement.

This method of prediction is strictly empirical and gives a much simplified spectrum. In general, this simplified spectrum is adequate for engineering purposes.



PREDICTED AV PSAA = 0.28 g
PREDICTED AV PSRV = 5.17 cm/sec
PREDICTED SPECTRUM ————
OBSERVED SPECTRUM ••••••••

Figure 1. PSRV for Station R-09.

6. DAMAGE PREDICTION

This is an area in which predictive capabilities [illegible] more research is necessary to define the correlation between measured quantities (i.e., [illegible] of motion, vibration characteristics of the structures, etc.) and the resulting damage. The methods developed for predicting damage have ranged from the extremely simple (i.e., sound engineering judgment) to the very complicated (i.e., the spectral matrix method).[3] It is difficult to justify the time and expense involved in the complicated methods due to the uncertainty in the relationship of damage to motion; on the other hand, the damage caused by nuclear explosions to date is too small to form an adequate basis for the sound engineering judgement method.

Two predictive techniques will be presented which are simple and inexpensive. Admittedly, the data sample on which these techniques are based is rather small but it is from motion measured and damage claims paid resulting from the Rulison event.

The first method is based on the peak vector velocity. Using the data from the Rulison detonation, a plot of peak vector velocity versus the claim-building ratio (i.e., number of damage claims paid per number of buildings in the locality) seems to show a linear relationship on a log log scale (Figure 2). This is a very small data sample upon which to base the relationship of damage to peak vector velocity; however, an analysis of the Bureau of Mines' data[4] shows a similar relationship (Figure 2) but occurring at higher values of velocity. In every case, the Bureau of Mines' velocity data was measured at the location where damage occurred, whereas, in the Rulison data the velocity was measured in one or, at most, two points and was assumed to apply to the whole locality. In deeply incised intermontane valleys, such as exist in this area, one can expect rapid lateral changes in near-surface geology and hence rapid changes in seismic response. An example of this is the De Beque case. In this case Station No. 1 agrees reasonably well with the linear relationship based on the Rulison data while Station No. 2, only 1000 feet away, is far more sensitive seismically and is much closer to the Bureau of Mines' data.

Since the regression equations are based on the hard-rock Rulison data, the damage prediction should be based on the Rulison relationship, not the Bureau of Mines' relationship.

The damage prediction technique is as follows:

1. Using Equation V_2 or Equation V_3 (depending upon the distance from the EW), properly scaled to the new yield and depth of burial (Equation S-6), determine the value of the peak vector velocity expected at the location.

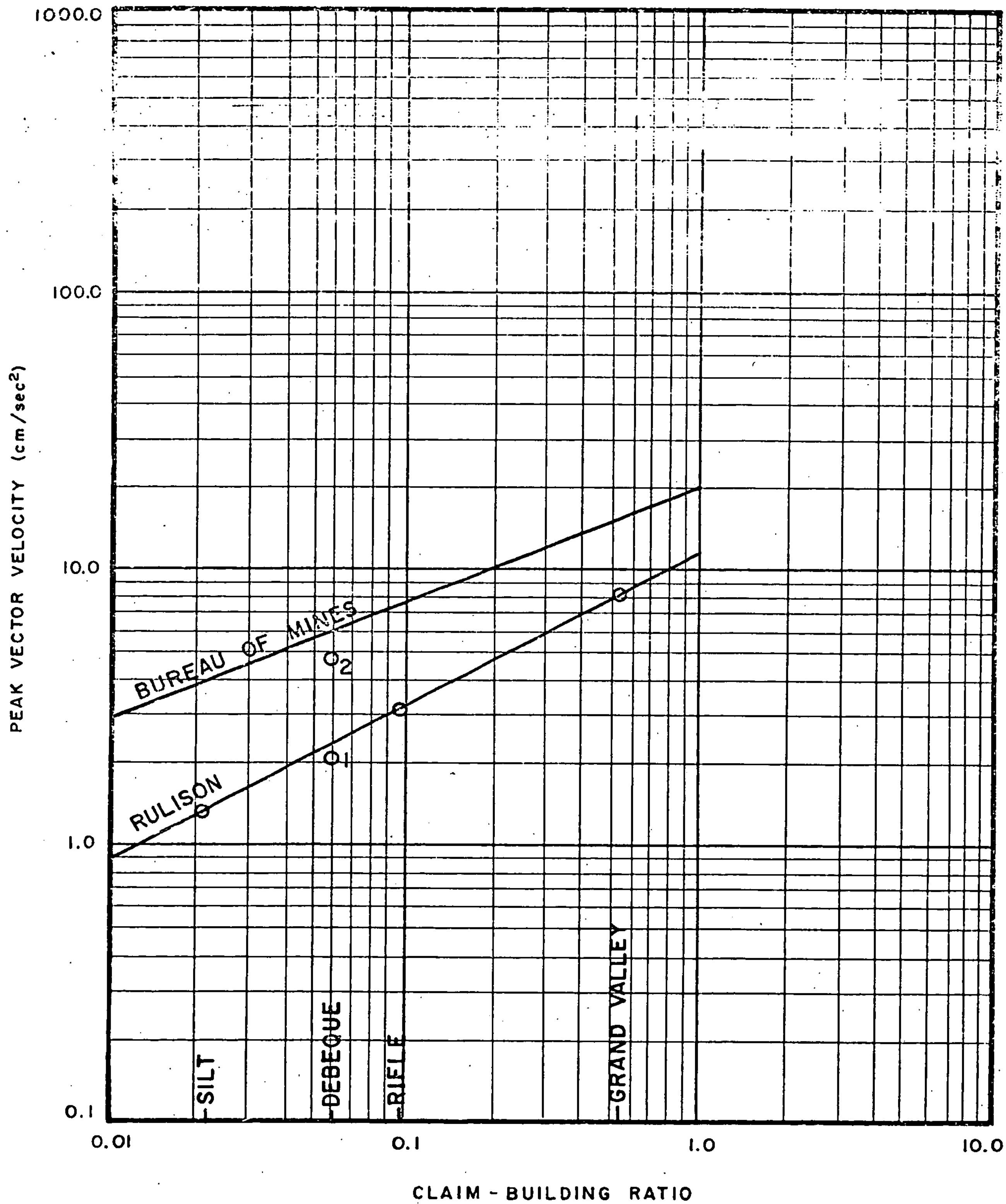


Figure 2. Seismic damage vs. peak vector velocity.

2. Using the linear relationship in Figure 2 determine the claim-building ratio and multiply by the number of buildings. This gives the number of expected damage claims at that location.

3. Multiply the expected number of claims by $300 (the average cost of Rulison claims) to determine the dollar value of damage at that location.

4. Perform steps 1 through 3 for all locations and sum the values. This gives the total value of the damage expected.

The second prediction technique, developed by M. Nadolski[5] at Lawrence Livermore Laboratory (LLL) using data from the Salmon event in Mississippi and Nevada Test Site data, is based upon the predicted average PSAA.

The technique is as follows:

1. Use Equation A_7 properly scaled to the new yield and depth of burial (Equation S_4) to predict the value of average PSAA expected.

2. Use Figure 3 (Nadolski-LLL relationship) to predict the claim-building ratio expected from this value of PSAA.

3. Multiply the claim-building ratio by the number of buildings to obtain the number of expected claims.

4. Multiply the number of claims by $300 to obtain dollar value of damage at this location.

5. Sum these dollar value figures for all locations to arrive at the total expected damage cost.

It should be pointed out that these damage predictions are limited to the low-cost, low-rise buildings typical of the Rulison area and do not include any claim adjusting or administrative costs. Any high-rise buildings or high-cost commercial installations should be analyzed by a competent structural engineering firm and any predicted damage added to the values obtained by the prediction methods described above.

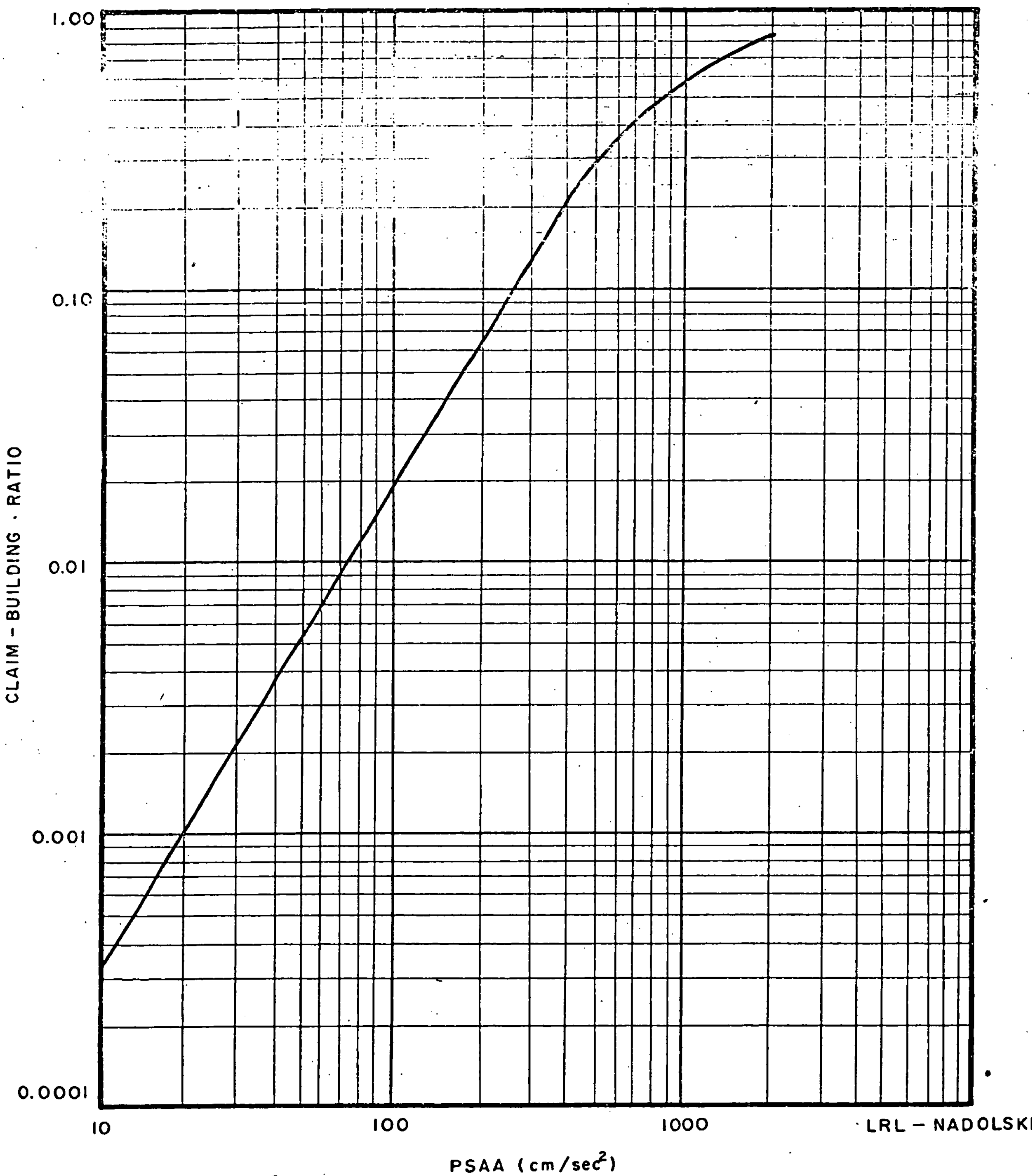


Figure 3. Seismic damage vs. PSAA.

APPENDIX A

ESCALATION EQUATIONS

SCALING EQUATIONS

Scaling for Yield Only

A $$a_1 = \left(\frac{w_1}{w_2}\right)^{0.66} a_2 \qquad S_1$$

V $$v_1 = \left(\frac{w_1}{w_2}\right)^{0.77} v_2 \qquad S_2$$

D $$d_1 = \left(\frac{w_1}{w_2}\right)^{0.87} d_2 \qquad S_3$$

Scaling for Yield and Depth of Burial

Where w is yield in kt and h is depth in ft.

A $$a_1 = \left(\frac{w_1}{w_2}\right)^{0.47} \left(\frac{h_1}{h_2}\right)^{0.58} a_2 \qquad S_4$$

$$= \left(\frac{w_1}{w_2}\right)^{0.66} \left(\frac{k_1}{k_2}\right)^{0.58} a_2 \qquad S_5$$

Where $k = \dfrac{h}{350w^{1/3}}$

V $$v_1 = \left(\frac{w_1}{w_2}\right)^{0.73} \left(\frac{h_1}{h_2}\right)^{0.12} v_2 \qquad S_6$$

$$= \left(\frac{w_1}{w_2}\right)^{0.77} \left(\frac{k_1}{k_2}\right)^{0.12} v_2 \qquad S_7$$

D $$d_1 = \left(\frac{w_1}{w_2}\right)^{0.99} \left(\frac{h_1}{h_2}\right)^{-0.33} d_2 \qquad S_8$$

$$= \left(\frac{w_1}{w_2}\right)^{0.87} \left(\frac{k_1}{k_2}\right)^{-0.33} d_2 \qquad S_9$$

These equations hold whether the scaling is being done to the peak vector, to the peak horizontal component, or to the PSAA and PSRV.

a = acceleration, either peak vector or peak horizontal component.

v = velocity, either peak vector or peak horizontal component.

d = displacement, either peak vector or peak horizontal component.

The derivation of the abo[illegible]

1. The $\frac{h_1}{h_2}$ ex[illegible] for accele[illegible] displacement have been deriv[illegible] er[7] and are 0.58 and -0.33, respective[illegible]

2. Simple harm[illegible] motion is assumed to describe the ground motion in the ela[illegible]ic region. This implies, in general, that $v = (ad)^{1/2}$.

Hence:

$$\frac{v_1}{v_2} = \left(\frac{a_1}{a_2}\,\frac{d_1}{d_2}\right)^{1/2}$$

$$= \left[\left(\frac{w_1}{w_2}\right)^{0.47}\left(\frac{w_1}{w_2}\right)^{0.99}\left(\frac{h_1}{h_2}\right)^{0.58}\left(\frac{h_1}{h_2}\right)^{-0.33}\right]^{1/2}$$

$$= \left(\frac{w_1}{w_2}\right)^{0.73}\left(\frac{h_1}{h_2}\right)^{0.12}$$, as given.

3. The yield exponents derived from NTS experience are 0.66, 0.77, and 0.85 for acceleration, velocity, and displacement, respectively[8]. The majority of these data come from detonations at a scaled depth of burial of $350w^{1/3}$. If one requires the equations to reduce to these exponents for depths of burial to the scaled depth, the exponents for $\frac{w_1}{w_2}$ become 0.47, 0.73, and 0.99 for acceleration, velocity, and displacement, respectively.

There is an uncertainty in deriving the regression equations and in scaling them to a new yield and depth of burial. The current published data do not furnish information of the amount of this uncertainty. As a result, to be conservative, a safety factor of 2.5 to 1 over predicted values of acceleration has been assumed for the calculations involving safety of personnel or for damage to high-value structures in the area. This assumption resulted from scaling the Gasbuggy data to the Rulison event and noting that all of the Rulison data fell within a 2.5 to 1 band.

DISPLACEMENT EQUATIONS

1. 0 to 296 km — Displacement Vector

   $d = 15.2R^{[illegible]}$ $\sigma = 1.37$ D_1

2. 0 to 22.8 km — Displacement Vector

   $d = 14.3R^{-1.65}$ $\sigma = 1.21$ D_2

3. 22.8 to 296 km — Displacement Vector

   $d = 17.2R^{-1.70}$ $\sigma = 1.42$ D_3

4. 0 to 296 km — Peak Horizontal Component

   $d = 9.25R^{-1.61}$ $\sigma = 1.45$ D_4

5. 0 to 22.8 km — Peak Horizontal Component

   $d = 6.24R^{-1.43}$ $\sigma = 1.29$ D_5

6. 22.8 km to 296 km — Peak Horizontal Component

   $d = 10.2R^{-1.63}$ $\sigma = 1.50$ D_6

d is in cm
R is in km

VELOCITY EQUATIONS

[illegible] km Velocity Vector

$916R^{-1.97}$ $\sigma = 1.53$ V_1

[illegible] km Velocity Vector

$v = 489R^{-1.72}$ $\sigma = 1.19$ V_2

3. 22.8 km Velocity Vector

$v = 1564R^{-2.09}$ $\sigma = 1.61$ V_3

4. 0 to 296 km Peak Horizontal Component

$v - 672R^{-1.94}$ $\sigma = 1.59$ V_4

5. 0 to 22.8 km Peak Horizontal Component

$v = 196R^{-1.46}$ $\sigma = 1.31$ V_5

6. 22.8 km to 296 km Peak Horizontal Component

$v = 1888R^{-2.17}$ $\sigma = 1.60$ V_6

7. 0 to 65 km

av. PSRV $= 994R^{-1.82}$ V_7

v is in cm/sec
R is in km

ACCELERATION EQUATIONS

1. 0 to 296 km — Vector Acceleration

   $a = 63.5R^{-2.33}$ — [illegible]

2. 0 to 22.8 km — Vector Acceleration

   $a = 19.7R^{-1.64}$ — σ = 1.5[illegible] — A_2

3. 22.8 to 296 km — Vector Acceleration

   $a = 139R^{-2.31}$ — $\sigma = 1.63$ — A_3

4. 0 to 296 km — Peak Horizontal Component

   $a = 36R^{-2.05}$ — $\sigma = 1.57$ — A_4

5. 0 to 22.8 km — Peak Horizontal Component

   $a = 9.05R^{-1.49}$ — $\sigma = 1.35$ — A_5

6. 22.8 to 296 km — Peak Horizontal Component

   $a = 107R^{-2.30}$ — $\sigma = 1.55$ — A_6

7. 0 to 65 km — Average PSAA

   $PSAA(g) = 28R^{-1.59}$ — A_7

a is in g
R is in km

APPENDIX B

EDITED RULISON DATA

DISPLACEMENT DATA

Station No.	Distance (km)	Vector Displacement (cm)	Peak Horizontal Component (cm)
R03	6.2	0.856	[illegible]
R02	6.4	0.589	0.310
R04	8.7	0.538	0.508
R25	10.6	0.236	0.218
R06	12.7	0.186	0.161
R07	13.3	0.155	0.137
R26	20.2	0.106	0.0693
R12	22.8	0.0992	0.0777
R17	32.4	0.0557	0.0356
R18	33.5	0.0413	0.0286
R19	40.4	0.0565	0.0494
R20	42.8	0.0343	0.0330
R28	56.2	0.0111	0.00957
R24	65.4	0.0122	0.0106
R48	66.8	0.0128	0.0110
R29	70.4	0.00900	0.00630
R43	75.2	0.00798	0.00798
R31	100.0	0.00426	0.00372
R30	100.0	0.0128	0.0117
R36	104.0	0.00437	0.00345
R38	127.0	0.00304	0.00260
R34	236.0	0.00225	0.00188
R41	296.0	0.00147	0.00141

Data from Reference 2.

VELOCITY DATA

Station No.	Distance (km)	Vector (cm/sec)	Peak [illegible] Component (cm/sec)
[illegible]	6.2	26.2	12.7
[illegible]	6.4	14.9	8.1
R04	8.7	14.9	13.7
R25	10.6	8.27	8.14
R06	12.7	5.39	5.28
R07	13.3	4.85	4.51
R26	20.2	3.13	2.19
R12	22.8	2.20	1.73
R17	32.4	1.34	1.07
R18	33.5	0.843	0.731
R19	40.4	0.918	0.830
R20	42.8	1.02	0.950
R22	55.4	0.160	0.146
R28	56.2	0.150	0.144
R24	65.4	0.365	0.293
R48	66.8	0.299	0.275
R29	70.4	0.104	0.099
R43	75.2	0.268	0.257
R31	100.0	0.0785	0.0612
R30	100.0	0.300	0.244
R36	104.0	0.0729	0.0636
R38	127.0	0.0538	0.0524
R34	236.0	0.0175	0.0148
R41	296.0	0.0100	0.00543

Data from Reference 2.

ACCELERATION DATA

Station	Range (km)	Vector Acceleration (g)	Peak Horizontal Component (g)
R01	6.2	1.20	0.636
R02	6.4	0.627	0.352
R04	[illegible].7	0.696	0.406
R25	10.6	0.550	0.358
R06	12.7	0.345	0.338
R07	13.3	0.194	0.149
R26	20.2	0.0962	0.0760
R12	22.8	0.102	0.0532
R17	32.4	0.0434	0.0353
R18	33.5	0.0307	0.0239
R19	40.4	0.0199	0.0190
R20	42.8	0.0375	0.0302
R22	55.4	0.00688	0.00655
R28	56.2	0.00482	0.00442
R24	65.4	0.0158	0.0118
R48	66.8	0.0113	0.00955
R29	70.4	0.00414	0.00406
R43	75.2	0.0113	0.0102
R31	100.0	0.00304	0.00275
R30	100.0	0.00895	0.00656
R36	104.0	0.00371	0.00273
R38	127.0	0.00177	0.00175
R34	236.0	0.000405	0.000355
R41	296.0	0.000238	0.000134

Data from Reference 2.

[illegible] RULISON DATA

Av. of PSAA between [illegible] and 12 Hz

Station	Distance (km)	Av. PSAA (g)
[illegible]	6.[illegible]	1.60
R0[illegible]	[illegible]	0.80
R04	[illegible]	1.30
R25	[illegible]0.6	0.83
R06	12.7	0.52
R07	13.3	0.44
R09	18.0	0.35
R26	20.2	0.15
R27	20.4	0.22
R12	22.8	0.17
R13	22.8	0.32
R14	29.8	0.095
R17	32.4	0.150
R18	33.5	0.076
R19	40.4	0.065
R24	65.4	0.038

Data from Reference 2.

APPENDIX C

REGRESSION GRAPHS

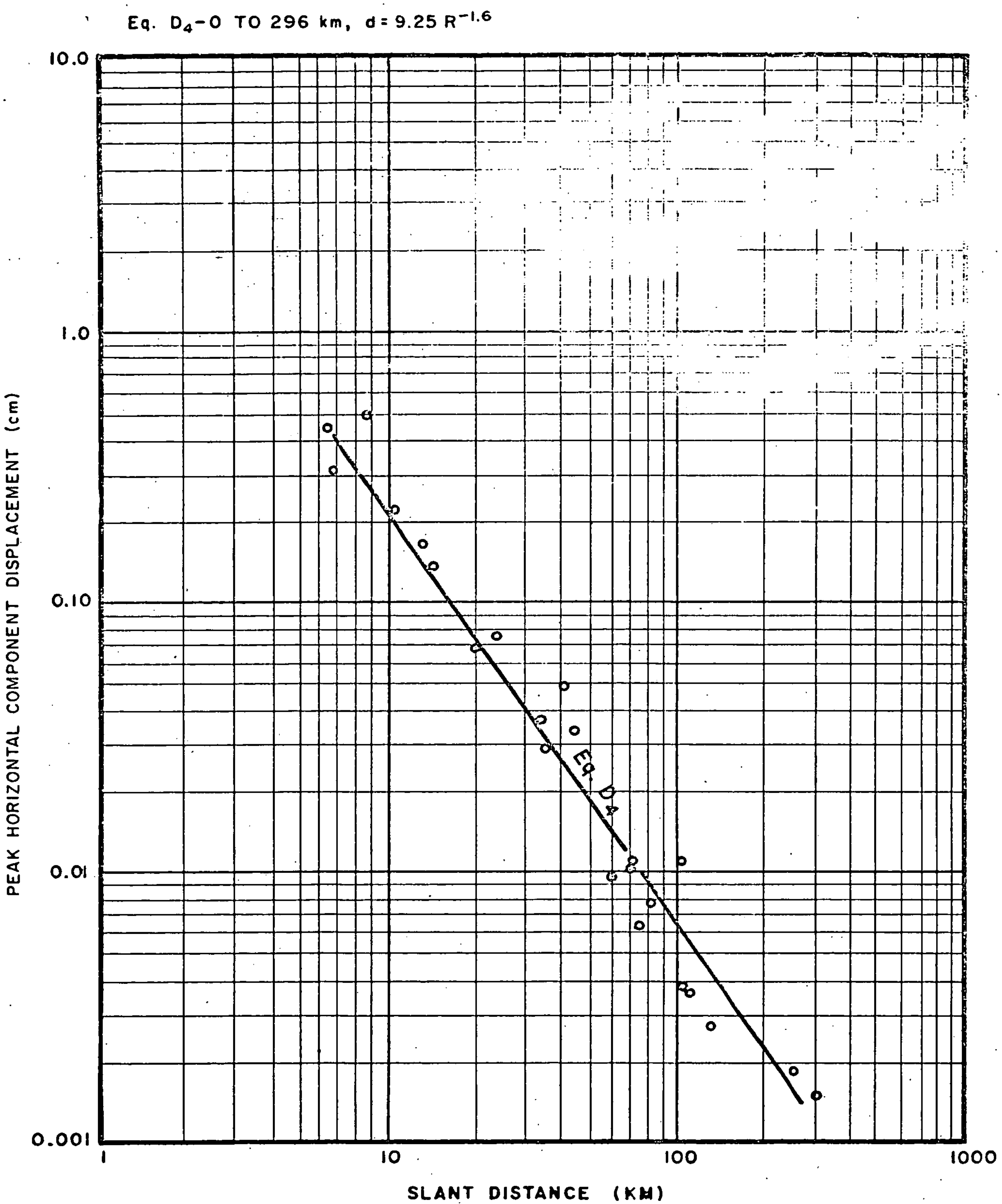


Figure C-1. Peak horizontal displacement vs. slant distance (0 to 296 km).

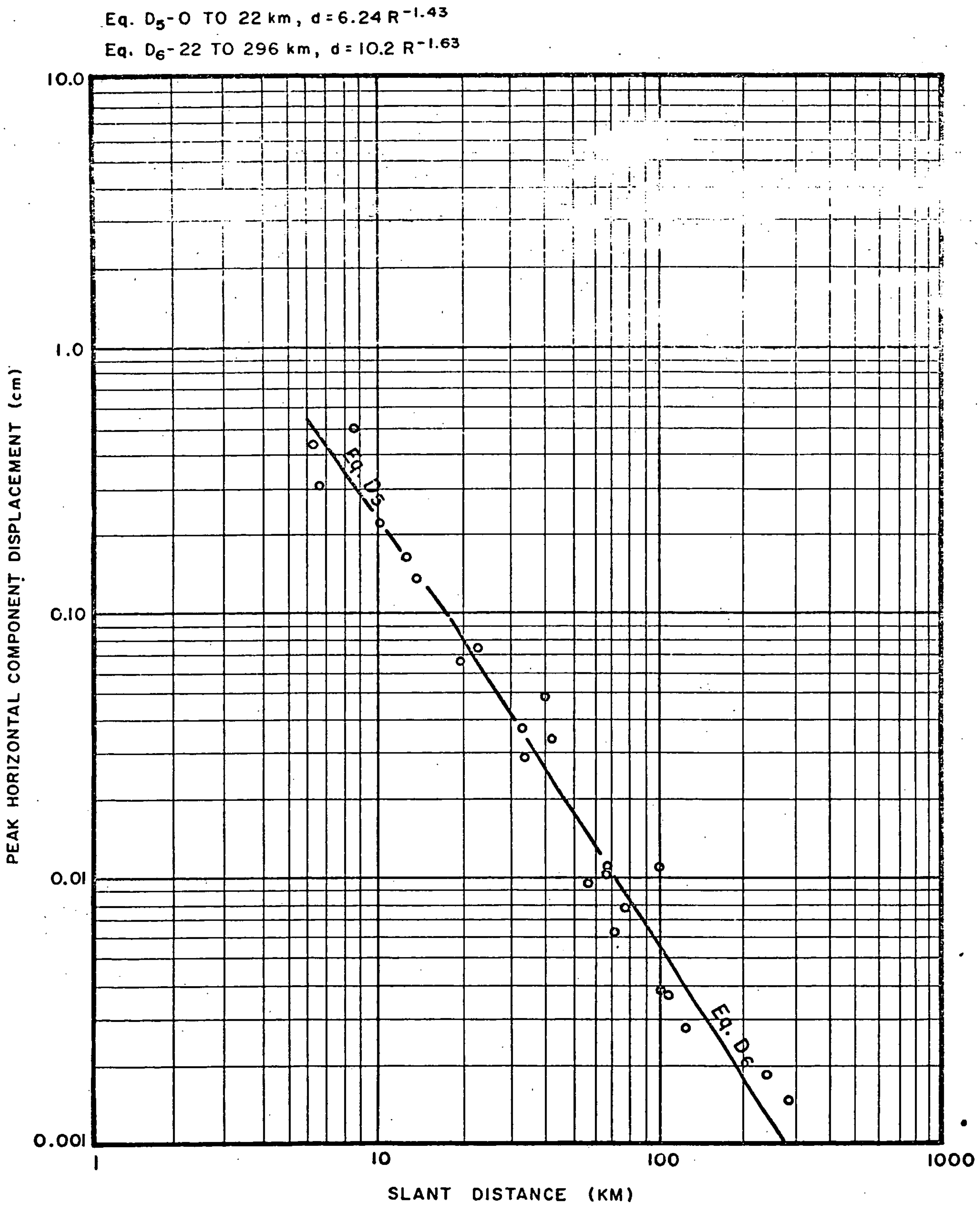


Figure C-2. Peak horizontal displacement vs. slant distance (0 to 22 km and 22 to 296 km).

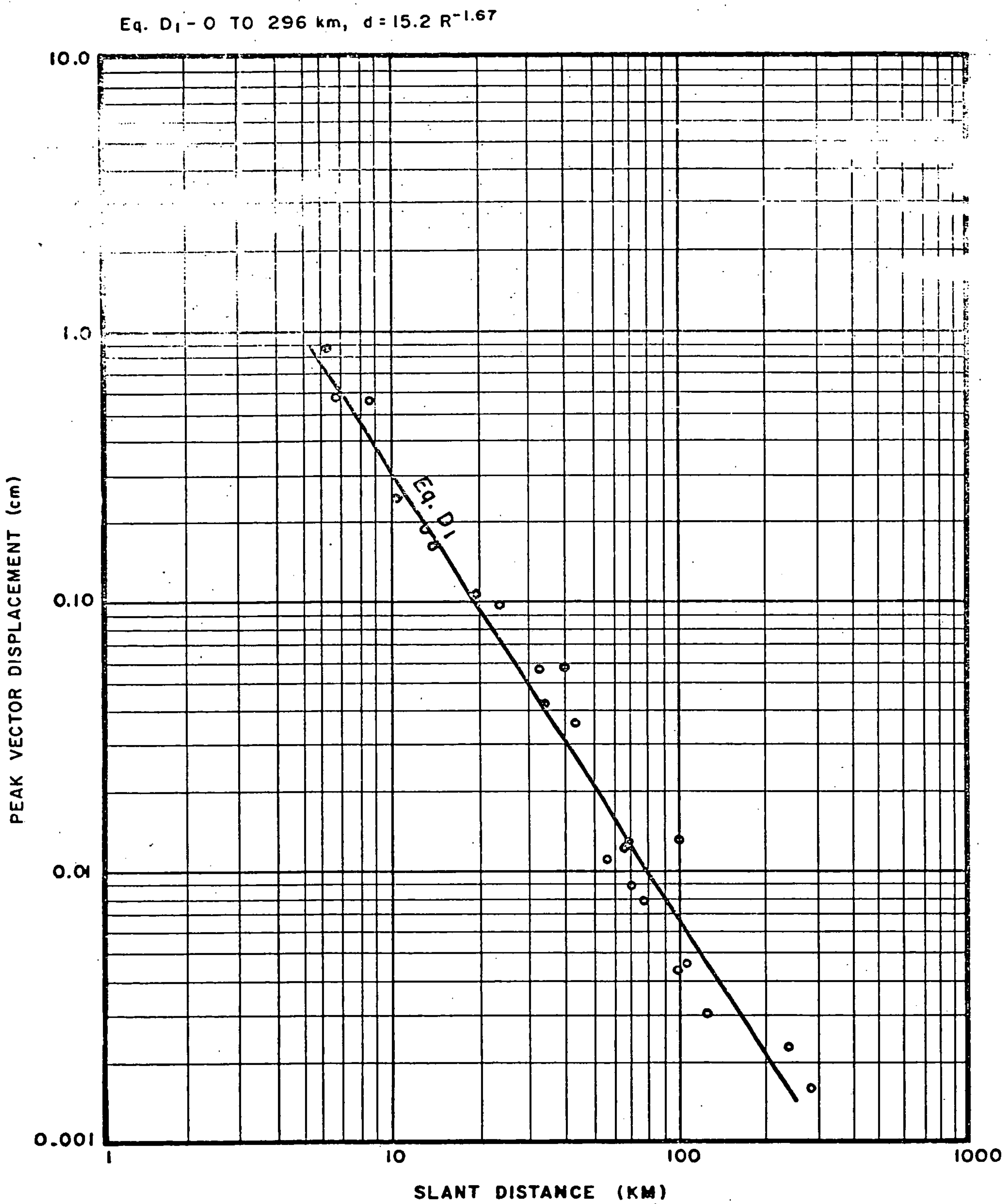


Figure C-3. Peak vector displacement vs. slant distance (0 to 296 km).

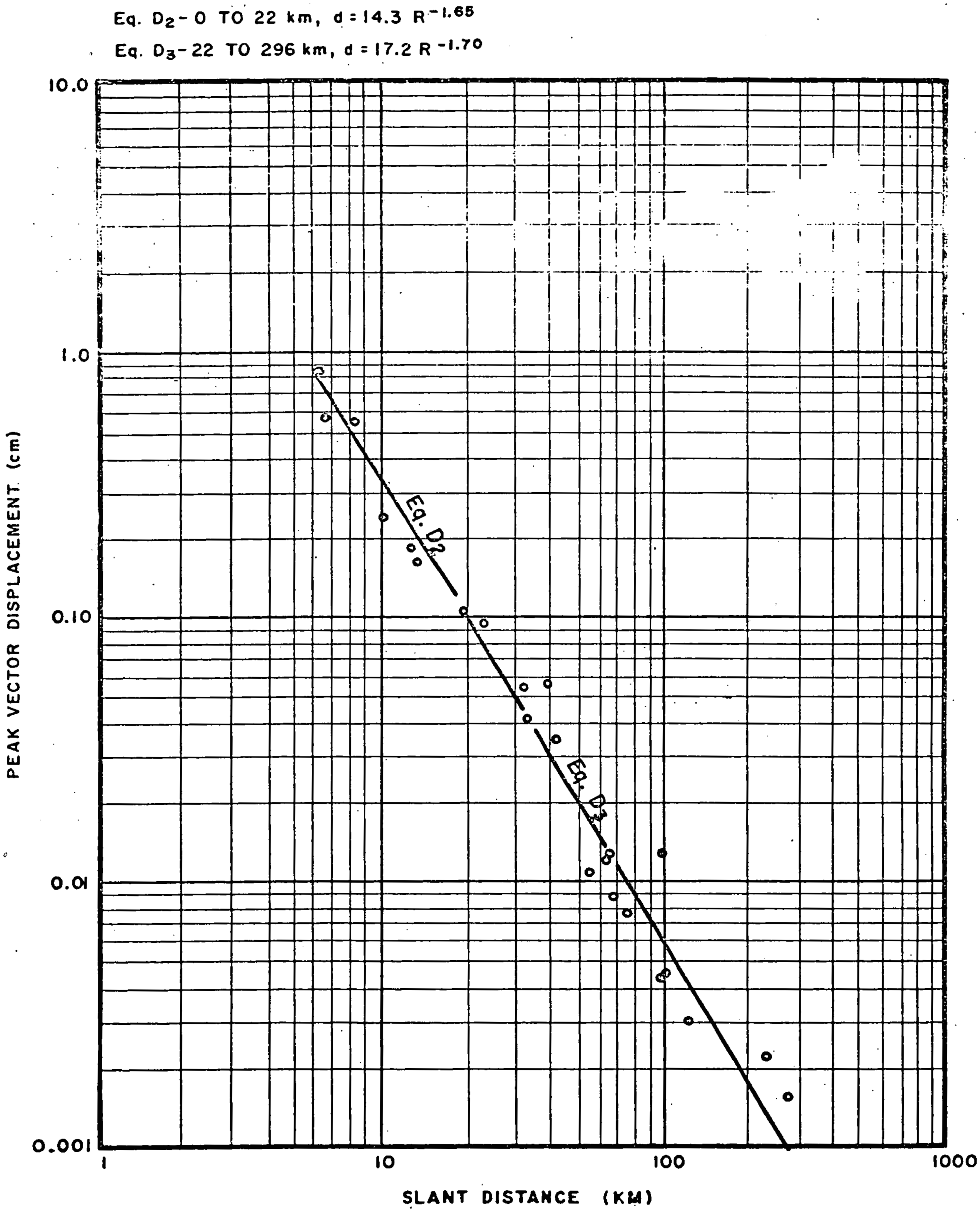


Figure C-4. Peak vector displacement vs. slant distance (0 to 22 km and 22 to 296 km).

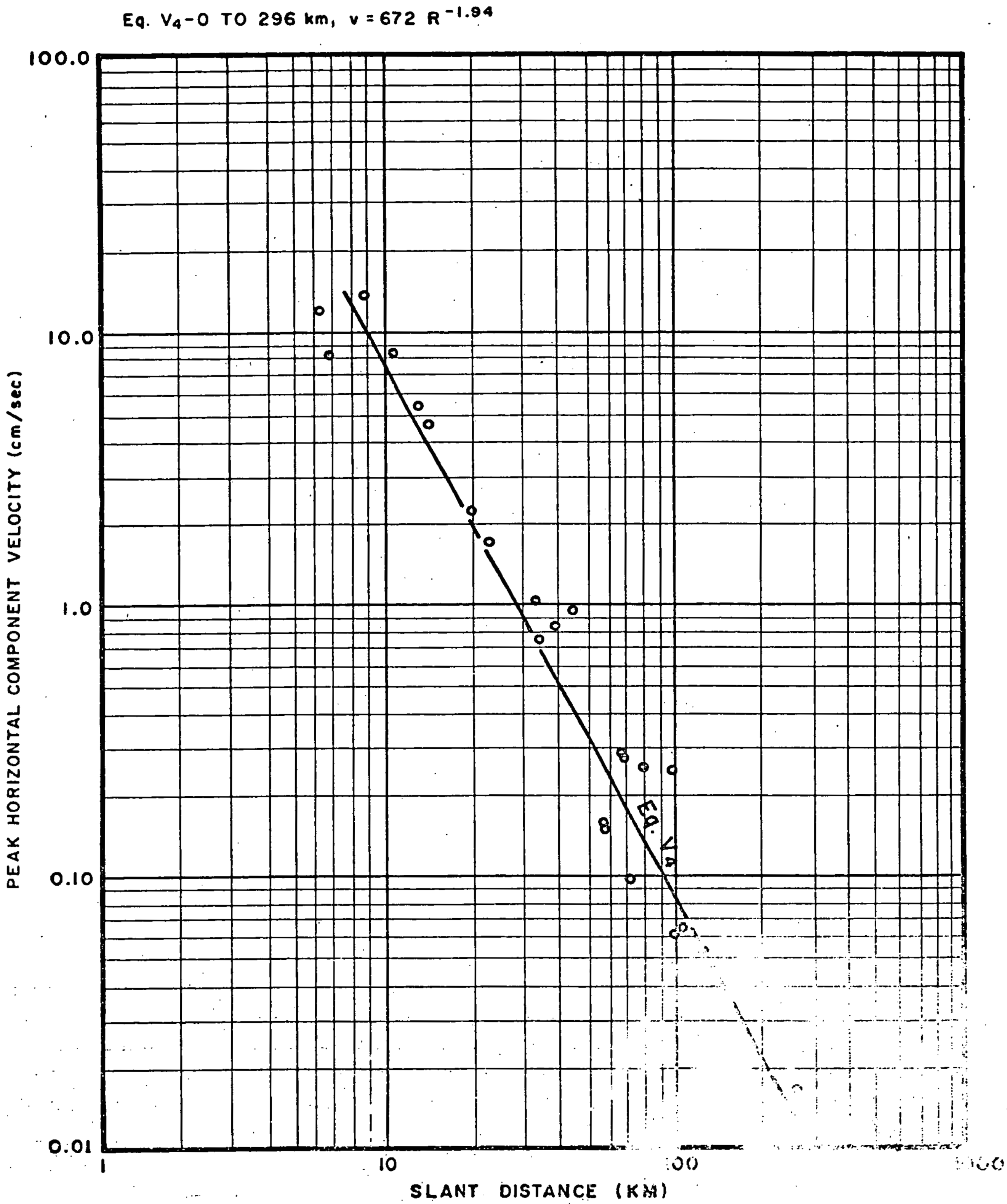


Figure C-5. Peak horizontal component velocity vs. slant distance (0 to 296 km).

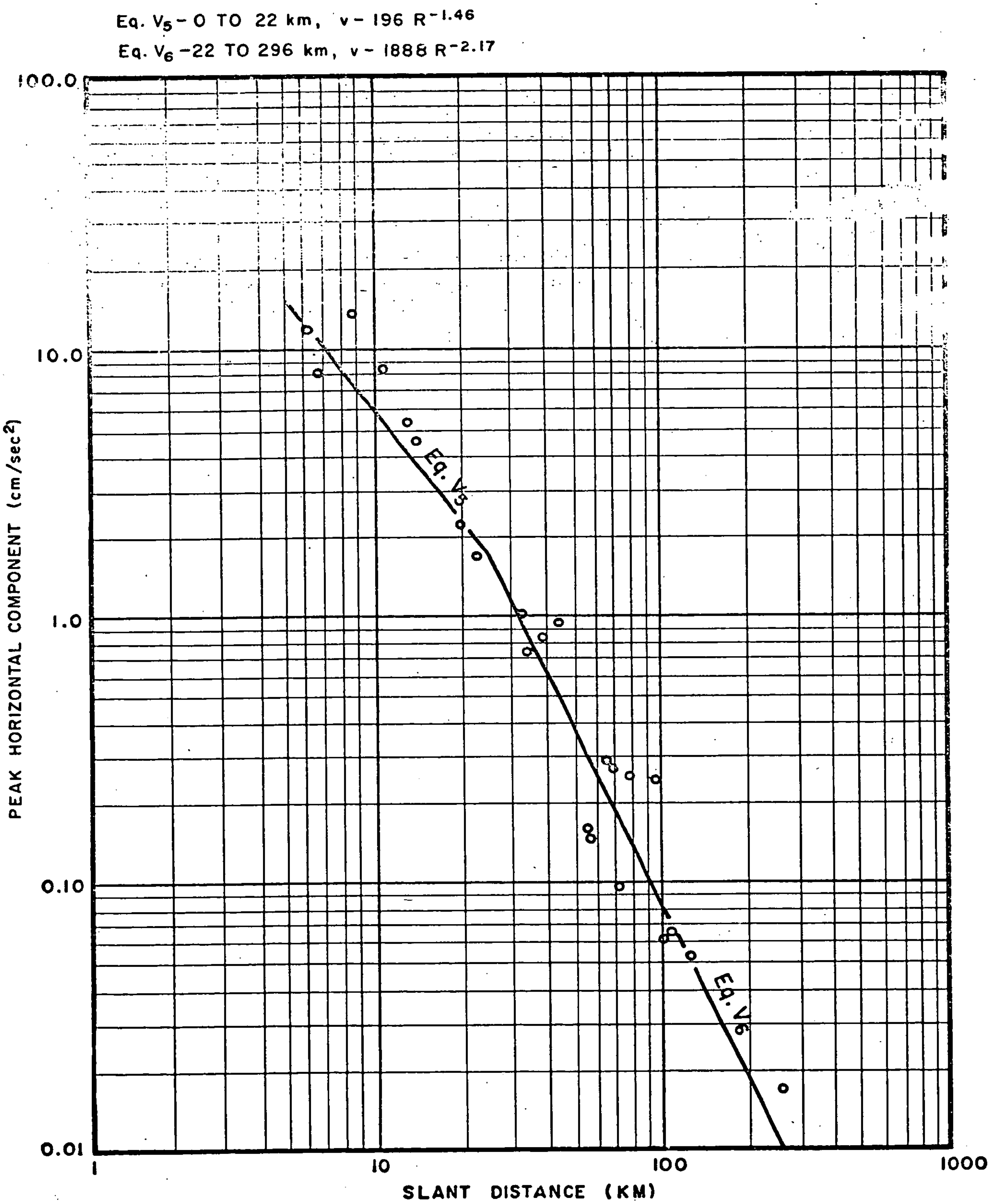


Figure C-6. Peak horizontal component velocity vs. slant distance (0 to 22 km and 22 to 296 km).

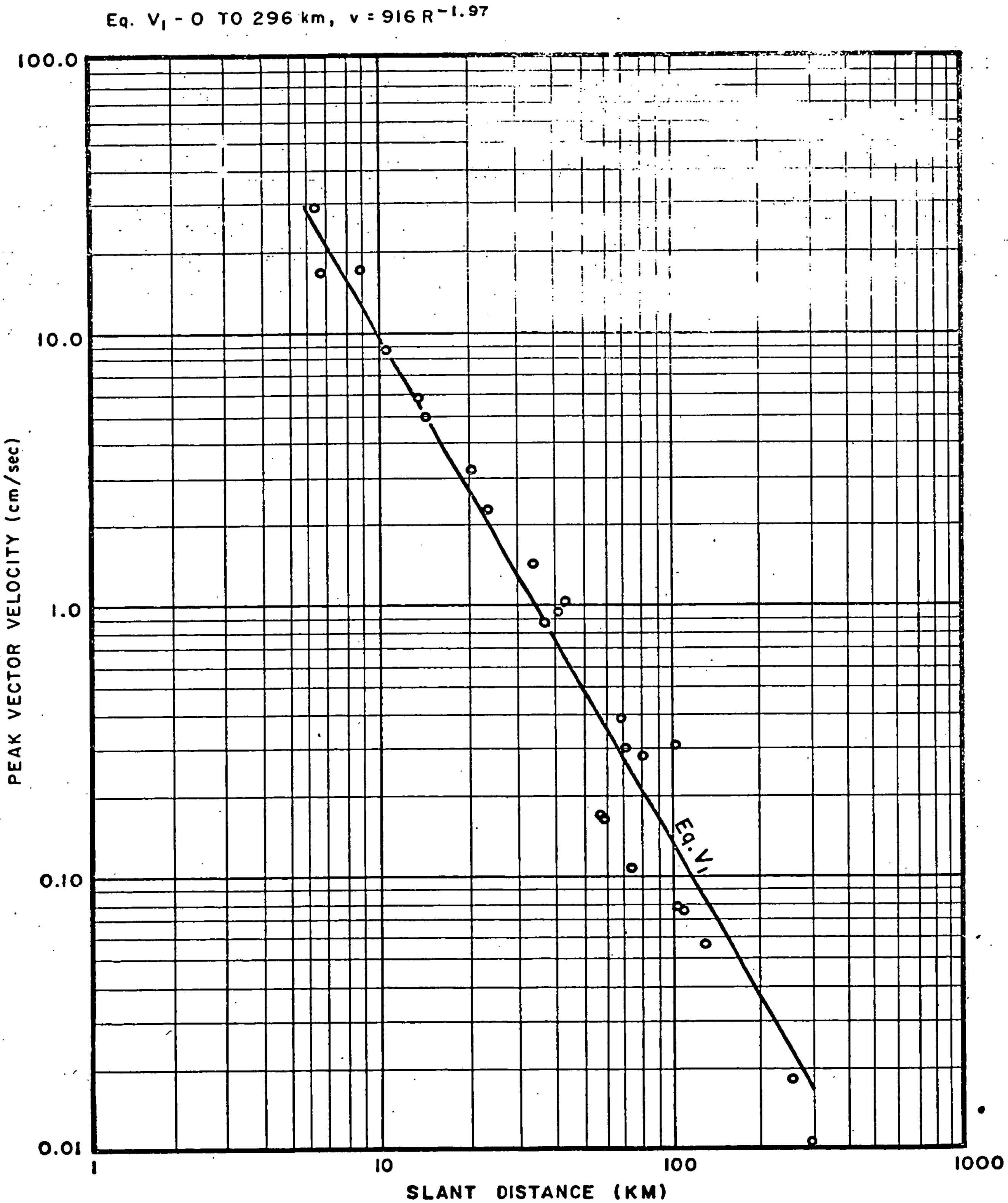


Figure C-7. Peak vector velocity vs. slant distance (0 to 296 km).

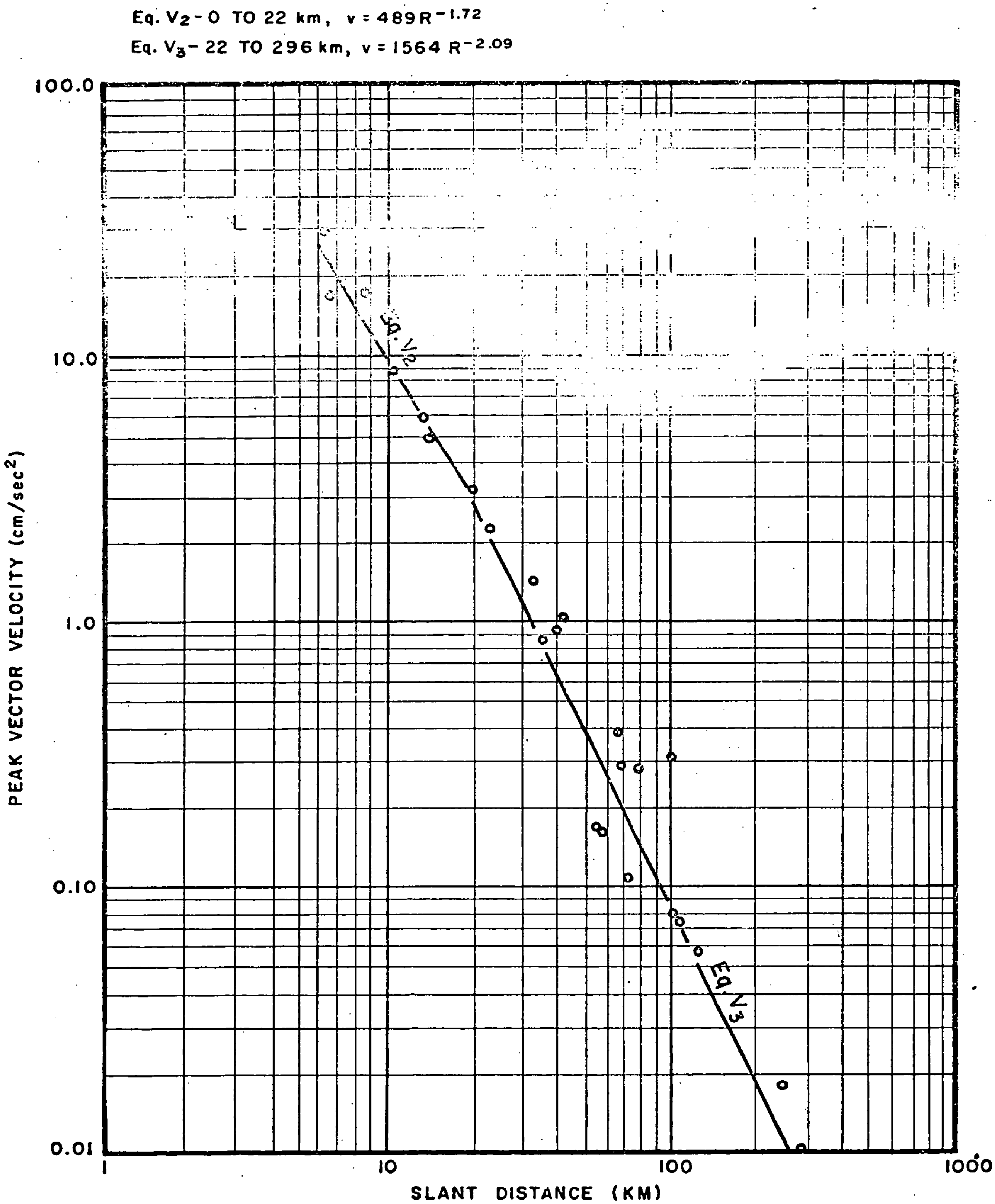


Figure C-8. Peak vector velocity vs. slant distance (0 to 22 km and 22 to 296 km).

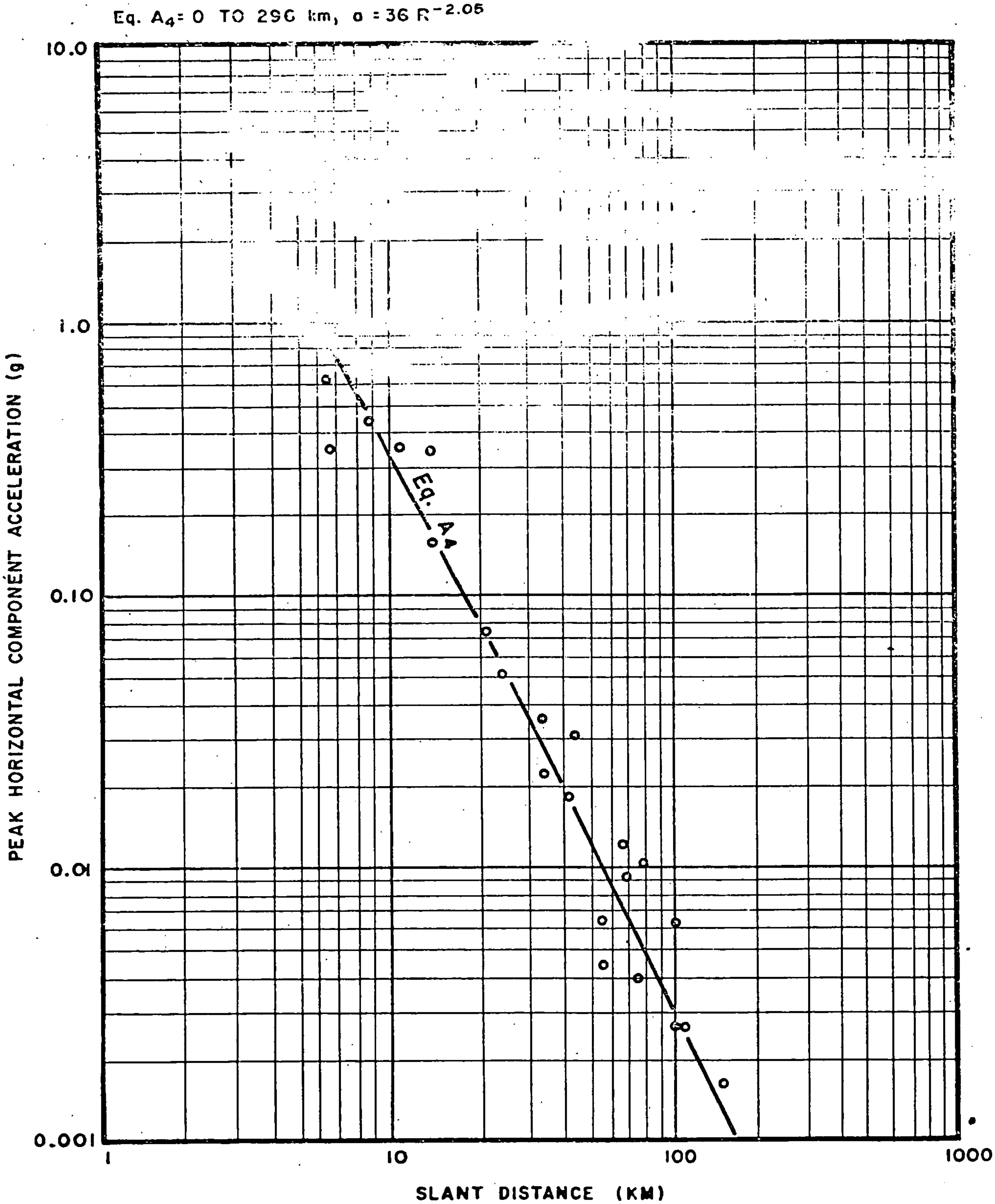


Figure C-9. Peak horizontal component acceleration vs. slant distance (0 to 296 km).

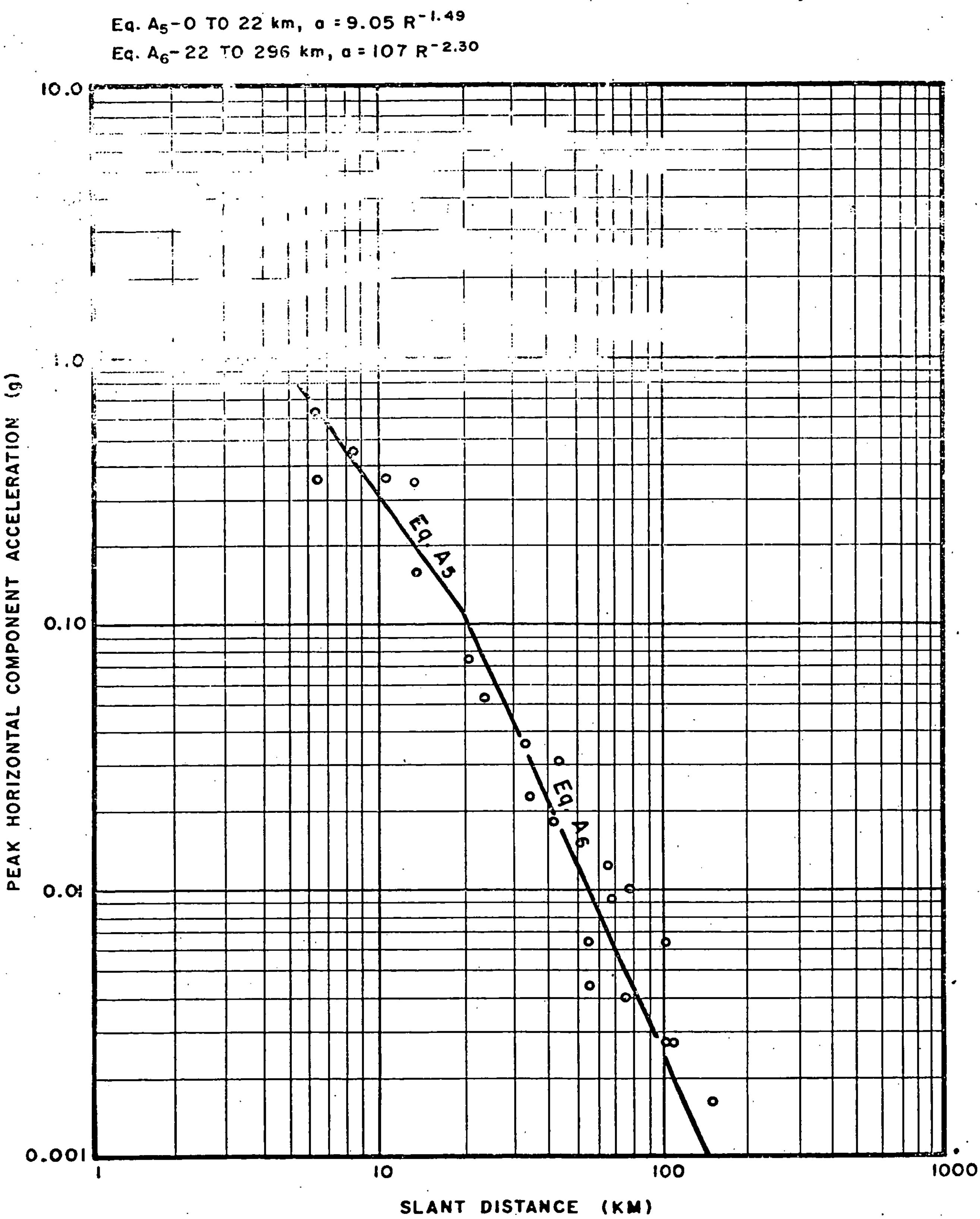


Figure C-10. Peak horizontal component acceleration vs. slant distance (0 to 22 km and 22 to 296 km).

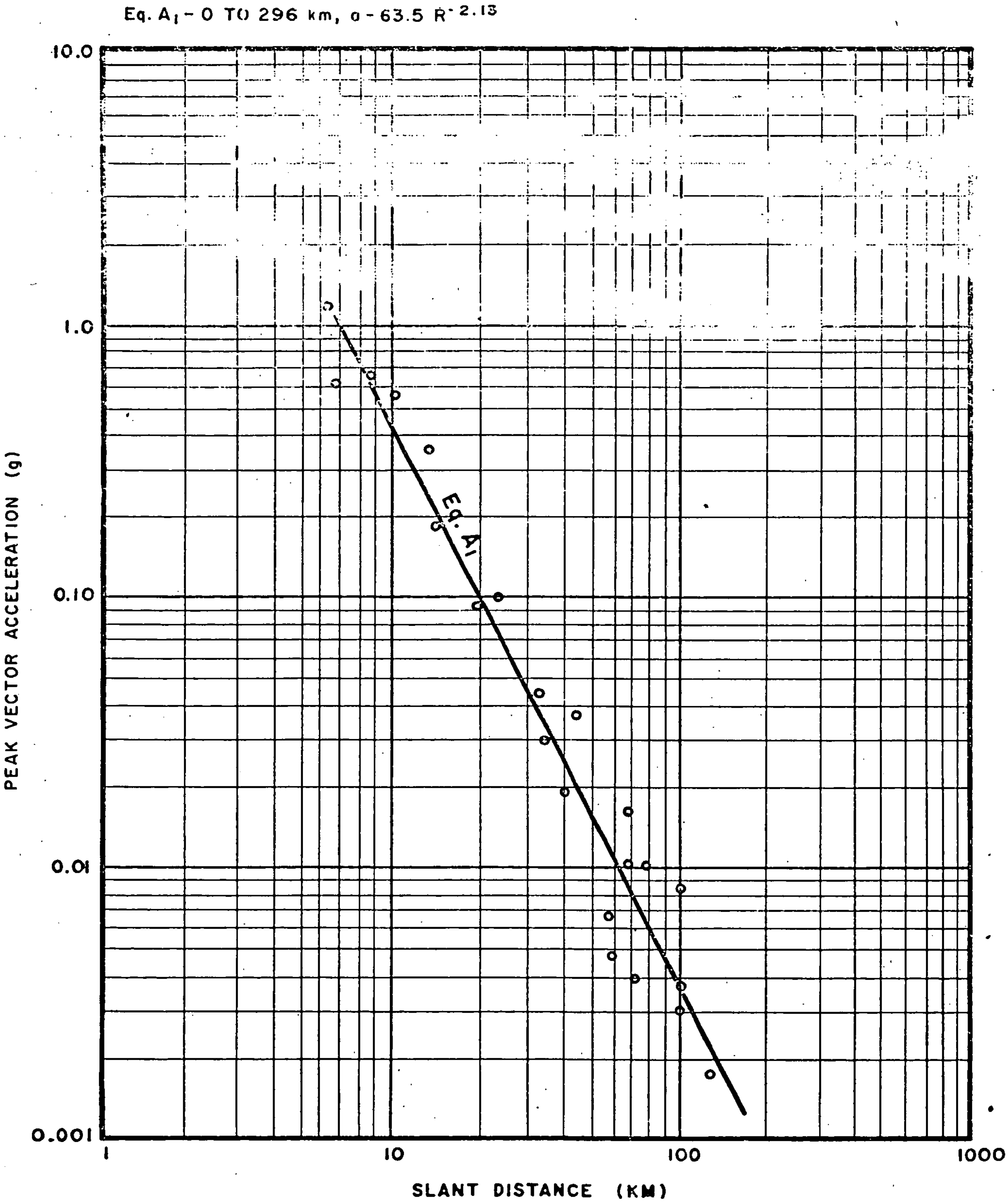


Figure C-11. Peak vector acceleration vs. slant distance (0 to 296 km).

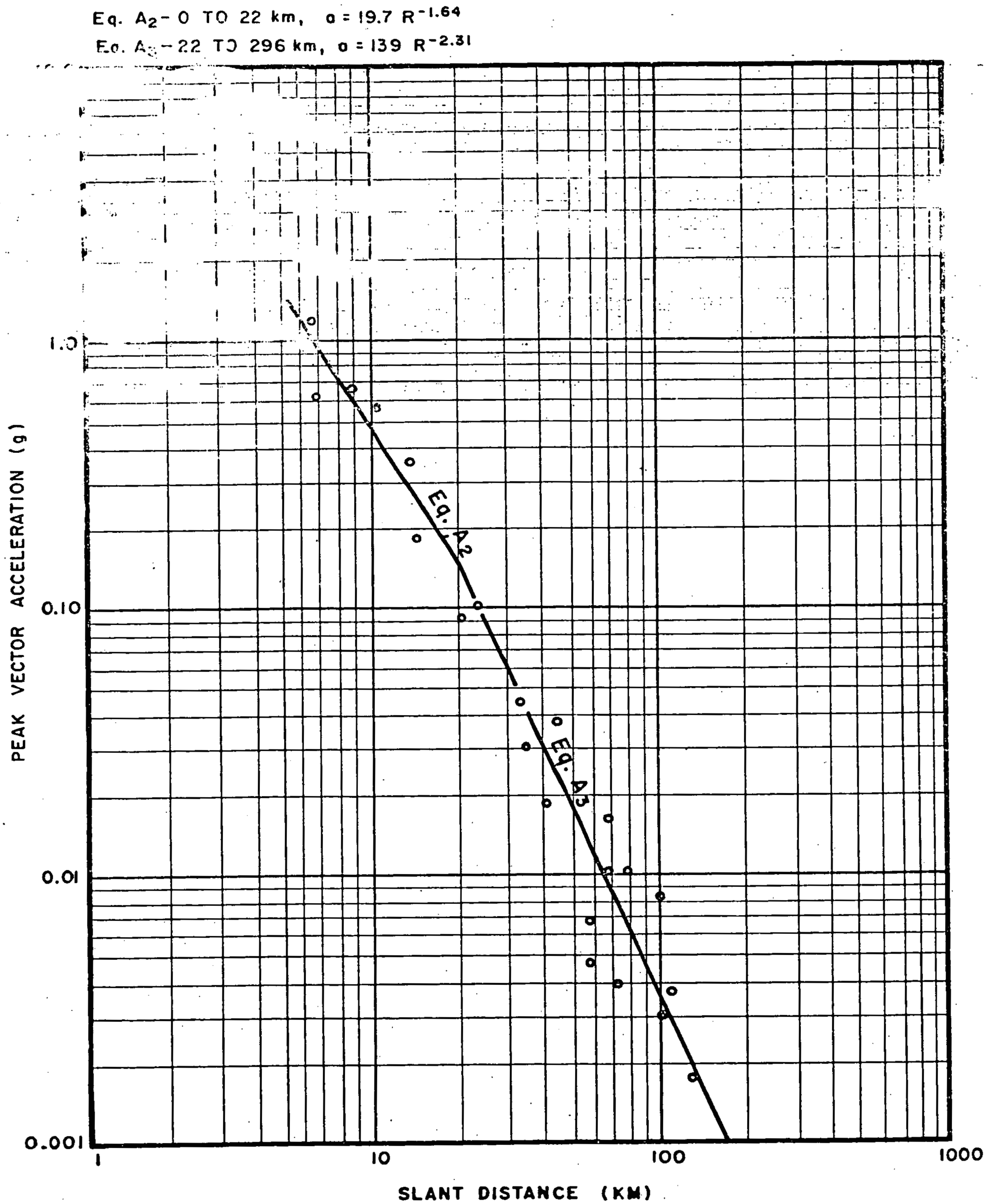


Figure C-12. Peak vector acceleration vs. slant distance (0 to 22 km and 22 to 296 km).

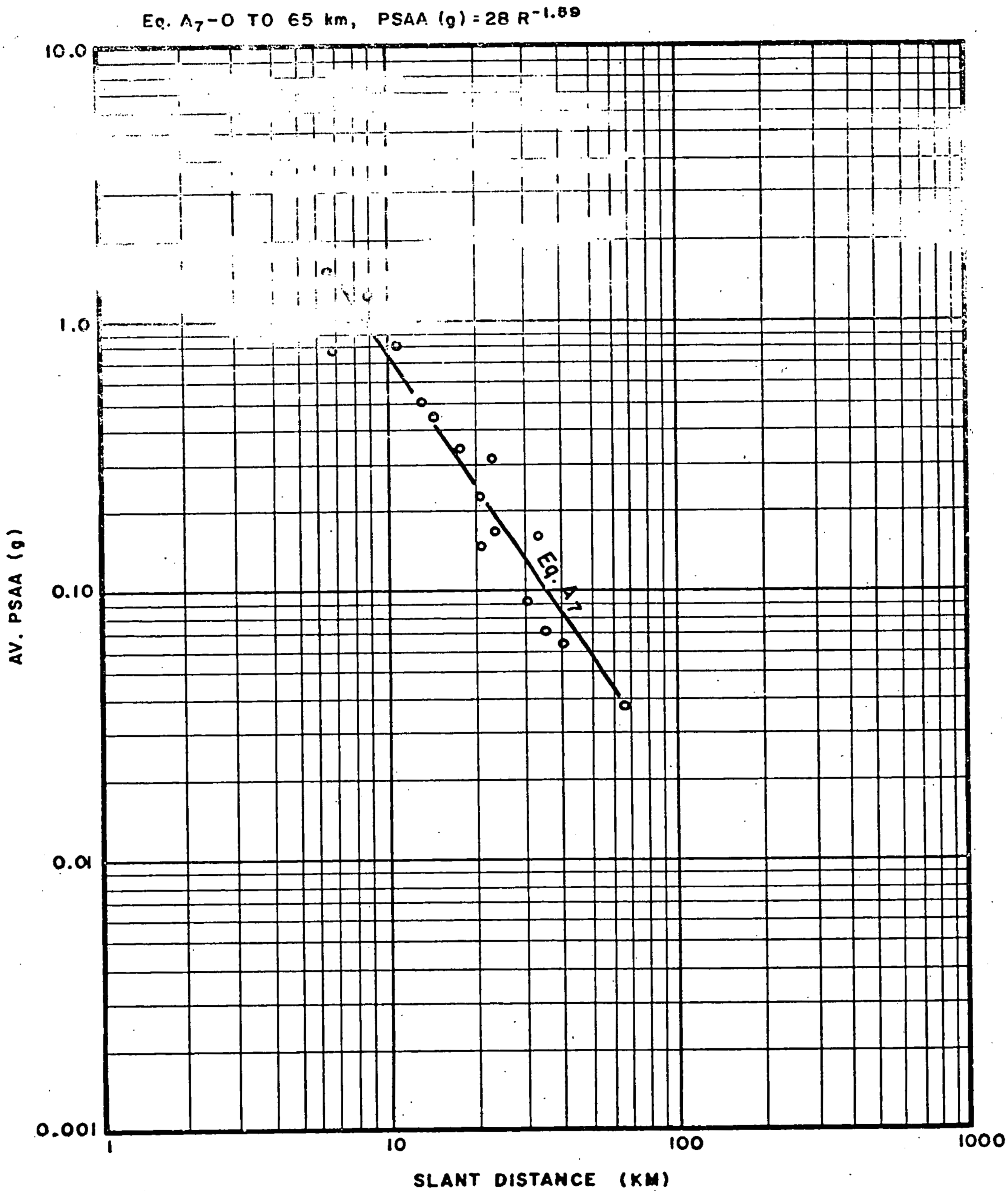


Figure C-13. Average PSAA vs. slant distance (0 to 65 km).

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